Techniques for precise thoracic endograft placement

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Precise endograft placement in the thoracic aorta is challenging due to the special local anatomy and unique hemodynamic blood flow. We are employing many techniques together to launch the endograft precisely to the target location: various debranching techniques to extend the proximal landing zone, magnified imaging with full exposition of the supra-arch branches and the proximal landing area to achieve a clear and accurate view, screen markers of the landing target for guidance of deployment, 1-2 cm proximally to the cranial landing marker before launching in case of any displacement, steady deployment of the endograft in hypotensive status or within the temporary heart asystole period induced by intravenous adenosine administration. If a balloon angioplasty or a proximal cuff is inevitable, the abovementioned techniques should be repeated. Our single center results have proved the combined techniques for precise thoracic endograft placement reliable, effective, simple and practical. (J Vasc Surg 2009;49:1069-72.)

Based on the experience of endovascular abdominal aortic aneurysm repair (EVAR), thoracic endovascular aortic repair (TEVAR) has been widely accepted in the past decade.[1] One of the differences between EVAR and TEVAR is the precise placement of endograft. In understanding the mechanism of endovascular aortic repair, it is similar to putting a tube in a running river; accurate placement in the desired target is crucial to the success. Precise deployment of the stent-graft is quite challenging in TEVAR procedure owing to the special local anatomy and unique hemodynamic blood flow.[2,3] We endeavored to employ a series of techniques to achieve the precise placement of the endograft in our institution; the results proved encouraging. The techniques for precise thoracic endograft placement are summarized here.

PATIENTS AND METHODS

The TEVAR results pooled in the database from July 1994 to December 2007 were retrospectively reviewed in our single center. A total of 265 cases underwent TEVAR procedures owing to a variety of thoracic lesions. All the procedures were carried out under general anaesthesia by the fixed TEVAR group in the operation room equipped with a mobile C-arm digital subtraction angiography (DSA) machine (Pulsera; Philips BV, Orlando, Fla).

How I Do It. Besides the general condition evaluation of the patient, the preoperative imaging assessment using thin slice cross-sectional contrast-enhanced Computed Tomography Angiogram (CTA), Magnetic Resonance Angiogram (MRA), or Digital Subtraction Angiography (DSA) is of great importance. Considering the precise thoracic endograft placement and the long-term results, we aggressively do debranching procedures to extend the proximal landing zone if the landing length is less than 1.5 cm. With the adjunction of different debranching techniques that have already been summarized and reported, we are treating more and more complex thoracic lesions with TEVAR procedures.[4] This technique proved helpful for precise thoracic endograft placement in TEVAR owing to the extended landing zone. During the TEVAR procedure, several techniques are adopted to achieve the precise endograft placement: (1) Full exposition and accurate view of the pathologic lesion and its related or involved local anatomy are the prerequisite for the ensuing procedures. The magnified aortography imaging accomplished in the anterior left oblique with 40°-45°is usually able to meet our demand; (2) Screen markers on the magnified imaging with full exposition of the supra-arch branches and the proximal landing area remain vital for guidance of the endograft deployment to the landing target (Fig 1). In this moment, it is also very important to keep the DSA machine and the patient in place with no occasional movement. Then the delivery system should be negotiated steadily and smoothly to the target location; (3) Put the cranial covered part of the endograft 1-2 cm proximally to the landing marker before launching is important in case of any displacement (Fig 2); (4) Steady deployment of the endograft according to the proximal landing marker on the closely watched screen is the key procedure for the final result. For

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Fig 1. Markers on the screen demonstrating the proximal landing target, the thoracic lesion, and its related anatomy.

Fig 2. The black arrow indicates the cranial covered part of the endograft is put proximally to the landing target before launching.

simple cases such as the lesions located in the descending aorta with enough proximal landing zone, we just deploy the endograft in the status of induced hypotention (70-90 mm HG) achieved with nitroglycerin or sodium nitroprusside. Retreat the cranial covered part of the endograft to the proximal edge of the landing marker and then deploy it steadily; stability of the whole delivery system and the super stiff guide wire is of great importance for this step. For complicated cases that will need placement of the thoracic

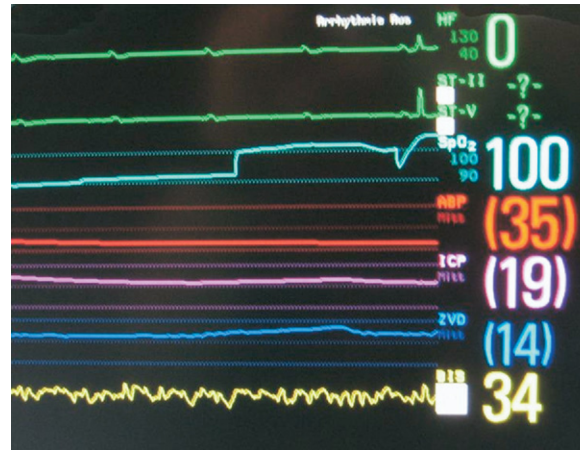

Fig 3. Heart asystole happens immediately after bolus administration of adenosine.

endograft near the aortic arch or in the ascending aorta, we normally deploy the endograft within the temporary heart asystole period induced by intravenous bolus of adenosine. While the endograft is in the desired position, 1 mg/kg adenosine was administered in a bolus intravenously, resulting in immediate 20-30 seconds heart asystole (Fig 3). Thus, the endograft can be precisely deployed in sufficient time without interference of downward blood flow induced by cardiac cycle. It is similar to putting a tube in a non-flowing river, which is much easier and more accurate than that in a running river.

If a balloon angioplasty or a proximal cuff is inevitable, the aforementioned techniques should be repeated.

RESULTS

Debranching techniques were used in 76 cases and the technical success rate was 100%. All the cases were carried out under guidance of markers on the screen with full exposed magnified imaging. Temporary cardiac arrest was undertaken in 168 cases. Precise positioning at a mean 2 ± 2 mm from the predetermined launch site was observed in all cases with cardiac arrest; there was no proximal or distal migration occurrence during deployment of the endograft. On the contrary, four cases had distal migration of more than 2 cm in the non-cardiac arrest cohort, which needed a proximal cuff to overcome the proximal endoleak. Among the four cases with distal migration, three cases had a Gore TAG device (W.L. Gore & Associates, Flagstaff, Ariz) and the other had an EndoFit device (LeMaitre Vascular, Burlington, Mass; LeMaitre Vascular now offers a next-generation version called the TAArget Thoracic Stent Graft, which has a redesigned delivery system and improved external fixation). Ten cases had immediate proximal type I endoleak, six cases were remedied with proximal cuff, and two cases were rescued with tri-lobe balloon, with two left untreated. One intraoperative massive bleeding from ascending aortic debranching anastomosis was rescued with the aid of pump. Neurological complications occurred in eight cases including five strokes and three paraplegia (two in type IV aneurysms and one transient in type III). The total mortality rate was 6.5%. All the extra-anatomical bypasses remained patent, all the stent-grafts implanted were patent, and there was no stent-graft kinking or collapse or dislocation.

DISCUSSION

Improved understanding of the native thoracic aortic environment where thoracic endografts are placed may aid in technique application for precise endograft positioning. Dynamic electrocardiographically-gated 64-slice cine CTA demonstrated that dynamics of the thoracic aorta and the arch vessels are impressive. There is a wide range of three-dimensional motions, and the aortic pulsatility is not evenly distributed.[2,3] To launch the endograft in the predetermined landmark, we should be very clear about the target location and its related anatomy. Therefore, magnified DSA imaging with full exposition of the arch and the supra-arch vessels is the prerequisite for further manipulation. Markers on the DSA screen provide accurate information where the endograft should be landed. Stability of the table and the patient should be kept in mind after angiogram. Most of the thoracic endografts currently available are unable to reposition once deployed. What we did differently from others in most of the cases for precise deployment is to induce temporary cardiac asystole using intravenous bolus injection of adenosine which has already been proven safe and simple.[4-6] Normally 60-90 mg adenosine can induce 20-30 seconds of cardiac arrest, which is sufficient for precise deployment of the stent-graft. The temporary cardiac asystole happens immediately after the bolus injection and recovers automatically within 20-30 seconds. For endografting of the descending thoracic lesions, we normally reduce the systolic blood pressure to 80-90 mm HG during deployment. This pharmacologically induced transient asystole or hypotension technique permits precise deployment of both self-expanding and balloon-expandable stent-grafts. Regardless, we do believe that any method to eliminate or reduce the force of aortic flow on the thoracic endoprostheses is helpful for precise thoarcic endograft placement. Rapid right ventricular pacing is now used in many centers.[7,8] This technique is widely applied for treating bradyarrhythmias. A 5-F bi-polar or quadpolar cardiac pacing catheter should be positioned in the right ventricular apex via the femoral or jugular vein and the pacing threshold should be checked once installed. An acceptable threshold was $\leq$ 1 mV. The pacemaker output was set to 4-5 mV. Ventricular pacing at a rate of 130 to 180 beats per minute can lower the systolic pressure to 50-60 mm HG,[7] and 160 to 200 beats per minute can reduce the systolic pressure to 20-30 mm HG.[8] The mechanism involves loss of atrioventricular synchrony and reduction of ventricular filling time, resulting in decreased left ventricular preload, stroke volume, and cardiac output. The advantage of this maneuver is that it is controllable and repeatable. The systolic pressure will drop down immediately and markedly once activation initiates, and it will almost immediately return to normal after inactivation of the pacemaker. Another method is partial right atrial inflow occlusion,[9,10] using a compliant occlusion balloon introduced through the femoral or jugular vein into the right atrium to inflate in the inferior or superior vena cava to occlude the inflow to the right atrium to reduce the cardiac preload. Potential complications of this technique include balloon rupture or migration and intracranial venous hypertension in the case of occlusion of the superior vena cava. Both techniques not only require knowledge of right cardiac anatomy but also need more apparatus or equipment and add more interventional maneuver to the TEVAR procedure. They would make the TEVAR procedure more complicated; therefore we do not apply them. We do believe that pharmaceutical approach is more simple and practical; it is easy to use and does not need any additional equipment or apparatus. We have not encountered any adverse effect using this technique.

CONCLUSION

Our single center experience demonstrated that a combination of debranching technique for extension of proximal landing zone, clear markers on the magnified DSA screen for guidance of positioning, induced hypotension, or temporary cardiac asystole for abbreviation of hemodynamic compromise can result in a precise endograft placement in TEVAR. The above techniques are safe, effective, and simple in selected patients and in experienced hands. They may eventually emerge as the preferred method for precise thoracic endograft placement in TEVAR.

AUTHOR CONTRIBUTIONS

Conception and design: DR, LQ
Analysis and interpretation: LQ, DR
Data collection: LQ
Writing the article: LQ
Critical revision of the article: DR
Final approval of the article: DR, LQ
Statistical analysis: LQ
Obtained funding: LQ
Overall responsibility: DR

REFERENCES

1. Kische S, Akin I, Ince H, Rehders TC, Schneider H, Ortak J, Nienaber CA. Stent-graft repair in acute and chronic diseases of the thoracic aorta. Rev Esp Cardiol 2008;61:1070-86.
2. van Prehn J, Vincken KL, Muhs BE, Barwegen GK, Bartels LW, Prokop M, et al. Toward endografting of the ascending aorta: insight into dynamics using dynamic cine-CTA. J Endovasc Ther 2007;14:551-60.
3. Muhs BE, Vincken KL, van Prehn J, Stone MK, Bartels LW, Prokop M, et al. Dynamic cine-CT angiography for the evaluation of the thoracic aorta; insight in dynamic changes with implications for thoracic endograft treatment. Eur J Vasc Endovasc Surg 2006;32:532-6.
4. Qu L, Raithel D. Two-year single-center experience with thoracic endovascular aortic repair using the EndoFit thoracic stent-graft. J Endovasc Ther 2008;15:530-8.
5. Dorros G, Cohn JM. Adenosine-induced transient cardiac asystole enhances precise deployment of stent-grafts in the thoracic or abdominal aorta. J Endovasc Surg 1996;3:270-2.
6. Plaschke K, Böckler D, Schumacher H, Martin E, Bardenheuer HJ. Adenosine-induced cardiac arrest and EEG changes in patients with thoracic aorta endovascular repair. Br J Anaesth 2006;96:310-6. Epub 2006 Jan 16.
7. Pornratanarangsi S, Webster MW, Alison P, Nand P. Rapid ventricular pacing to lower blood pressure during endograft deployment in the thoracic aorta. Ann Thorac Surg 2006;81:e21-3.
8. Nienaber CA, Kische S, Rehders TC, Schneider H, Chatterjee T, Bünger CM, et al. Rapid pacing for better placing: comparison of

techniques for precise deployment of endografts in the thoracic aorta. J Endovasc Ther 2007;14:506-12.

9. Marty B, Morales CC, Tozzi P, Ruchat P, Chassot PG, von Segesser LK. Partial inflow occlusion facilitates accurate deployment of thoracic aortic endografts. J Endovasc Ther 2004;11:175-9.

10. Lee WA, Martin TD, Gravenstein N. Partial right atrial inflow occlusion for controlled systemic hypotension during thoracic endovascular aortic repair. J Vasc Surg 2008;48:494-8.

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INVITED COMMENTARY

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The authors have developed an excellent thoracic endovascular aneurysm repair (TEVAR) practice with commendable results. The techniques described in this article are useful for TEVAR when using single-stage delivery systems where the outer jacket is slowly withdrawn as the endograft self-expands. Specifically, beginning placement "1 to 2 cm proximally to the landing marker" is necessary when the strong forces required to pull back a stiff outer jacket risk distal dislodgement of the entire system.

Adenosine arrest is useful when there are potential windsock effects during a prolonged deployment sequence. Interestingly, vasodilator-induced arterial hypotension may actually increase cardiac output in some patients by reducing afterload.

Additional supplementary techniques may be used with these and other types of delivery systems. For example, modern fixed imaging systems allow three-dimensional roadmapping without the need for marking on the monitor. Multiple gantry angle imaging can be very useful when the endograft is not deploying perpendicular to the imaging beam, parallel to the aortic neck, and perpendicular to the origin of the closest preserved aortic branch. With multistage deployment systems, where the endograft is still partially constrained after the outer jacket is withdrawn, repeated imaging in multiple planes with small volumes of contrast can be performed before and after fine repositioning, and then the endograft is completely deployed in the final stage. Repeat arteriography and repositioning are particularly useful when removal of a stiff jacket alters the thoracic arch anatomy or the angulation of the endograft.

Specific thoracic guidewires with precurved shapes for the thoracic arch, brachial-femoral "tug-of-wire" technique, tip deflection tricks, and tensioning the guidewire along the greater curve can also be used to improve precision with rapid deployment systems that do not require induced hypotension or cardiac arrest. In the future, deployment systems that allow trial deployment, complete reconstraining, repositioning, and redirecting the endograft will allow TEVAR practitioners ideal control over the placement of the devices in this challenging thoracic aortic environment. Until then, these and other techniques that Drs Lefeng Qu and Dieter Raithel have described should be familiar to the TEVAR practitioner.